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Use of tree hollows by the Green Tree Frog *Litoria caerulea* at East Point Reserve, Darwin

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The Green Tree Frog *Litoria caerulea* has one of the broadest geographical ranges of all Australian hylids. Its distribution extends in a wide arc from south of Broome (Anna Plains) through the Kimberley, across the Top End south and inland to the Tanami, Sturt Plateau and Barkly Tableland, and down the east coast through Queensland to northern New South Wales (Barker *et al.* 1995, Tyler *et al.* 1983, P. Horner, pers. comm.). It is also extralimital in New Guinea (Tyler 1999). The three other species in the *Litoria caerulea* complex each have relatively restricted distributions. *Litoria gilleni* occurs in the central Australian ranges (MacDonnells), *Litoria splendida* in the East Kimberley and Keep River region, and *Litoria cavernicola* is a habitat specialist confined to the Mitchell Plateau of the Kimberley. *Litoria gilleni* was originally described by Spencer (1896) and is currently considered a good species (*e.g.* Cogger *et al.* 1983, Bedford 2000), as are *L. cavernicola* (Tyler & Davies 1979) and *L. splendida* (Tyler *et al.* 1977). Tyler and Davies (1986) included *L. gilleni* under *L. caerulea* which was noted as occurring "throughout the Northern Territory".

Whilst the three geographically restricted members of the *Litoria caerulea* complex are largely or exclusively rock dwelling (saxicoline) species that use moist microclimates in rock crevices (often near sources of permanent water) as retreats, *L. caerulea* uses tree hollows as shelter sites across its range. It occurs in a wide range of habitats including savanna, pindan, eucalypt woodlands and forests, closed monsoon forests and thickets, and has also been recorded from mangroves (J. Smith, pers. comm.) and mango orchards (R. Peng, pers. comm.). In many parts of Australia, including the Top End, it has become accustomed to human habitation and commonly breeds in garden ponds.

As part of ongoing physiological studies of Top End amphibians, I have been involved in investigations of the biology of *L. caerulea,* with the focus of the work at East Point Reserve near Darwin. The Reserve includes a mosaic of grassed and revegetated areas, with a single patch of relatively undisturbed coastal rainforest occupying an area of approximately 25 ha within which the studies have been conducted. The vegetation at the study site is defined as a low closed coastal dry monsoon forest (*sensu* Russell-Smith 1991). It consists of a mixed array of trees, shrubs and vines including many Malesian floral elements and generally extends to a height of 9–12 metres. Conditions under the dense rainforest canopy are highly suited

to tree frogs, incorporating extensive shade, warm and relatively constant temperatures, high humidity, and minimal air movement particularly near the forest floor (McCay 2003). These last two factors in particular serve to reduce rates of evaporative water loss (e.g. Christian & Parry 1997, Tracy 1976) in what is a seasonally dry (monsoonal) and therefore potentially highly desiccating environment.

At East Point the frogs are primarily active during the wet season. They are probably entirely nocturnal, emerging soon after dusk and moving to the canopy, the forest floor or low perches on branches. Breeding takes place opportunistically during the wet season, calling activity being particularly intense during heavy rain. Frogs tend to remain within tree hollows during the coolest months of the dry season (G. Miles, pers. comm.), but are relatively active when weather conditions are suitable, i.e. during periods of high night time humidity or warmer weather.

One aspect of the investigations at East Point has been to examine the use of daytime refuges by *L. caerulea*. Individual frogs have been followed to their daytime refuges with the aid of radio-tracking (telemetry) techniques, and a pattern of use of hollows has emerged. Frogs that were tracked were given a unique identification number or code, and tree hollows were numbered after a frog had been followed and the location of the hollow determined. In certain instances, where hollows were high above the ground, the tree species could be identified but it was not possible to measure the attributes of the hollow.

Tree species that form hollows were identified using Brock (1997), Wightman and Andrews (1989) and Booth *et al.* (2001) and with reference to collections maintained at the Northern Territory (NT) Herbarium. A list of plant species for the area was derived from NT Herbarium records and Wightman and Andrews (1989). Based on this information, approximately 140 plant species occur in the monsoon forest at East Point (excluding artificial plantings). This includes 48 species of tree (defined as plants with a robust trunk and capable of exceeding five metres in height), only nine of which are utilised by the frogs as daytime refuges (Table 1). Several trees of *Litsea glutinosa, Drypetes deplanchei* and *Ganophyllum falcatum* were used as hollows, whereas for the remaining six species there were only single cases of hollow use (Table 1).

Only certain types of trees in the monsoon forest readily form hollows, and of these only some appear to be suitable as refuge sites for frogs. Hollows vary in structure as a result of their mode of formation. In *Litsea glutinosa* knots form at regular intervals along the trunk at previous points of attachment for branches and become small hollows; hollows also form in the trunk of dead individuals of this species (Table 1). Convolutions of the trunk in *Drypetes deplanchei* form a vertical envelope or fissure of varying extent which may become almost entirely enclosed. Hollows of this type tend to be larger but probably do not provide as much protection as closed hollows. *Ganophyllum falcatum* forms cylindrical hollows along main branches, some of which are many metres above the ground. Dead and decaying trees are also used and termites

are an important agent of hollow formation. However, our data indicate that trees are not utilised by frogs after they have fallen to the ground.

Table 1. Characteristics of trees with hollows that were utilised as daytime refuges by *Litoria caerulea* at East Point Reserve (n = 25 hollows). (H = Hollow number, Frog ID = identification number or code of frog/s that used the hollow)

H	Frog ID	Tree species	DBH (cm)	Height (m)
1	10, X	*Litsea glutinosa*	10	9
7	D	*Litsea glutinosa*	6	7
22	11	*Litsea glutinosa*	10	6
25	11	*Litsea glutinosa*	25	10
26	11	*Litsea glutinosa*	15	9
27	11	*Litsea glutinosa*	12	12
2	A	*Drypetes deplanchei*	22	10
3	B	*Drypetes deplanchei*	20	10
5	C	*Drypetes deplanchei*	25	11
9	9	*Drypetes deplanchei*	20	9
23	11	*Drypetes deplanchei*	21	9
6	10, 8	*Ganophyllum falcatum*	60	14
10	2	*Ganophyllum falcatum*	30	11
11	8	*Ganophyllum falcatum*	50	10
16	8	*Ganophyllum falcatum*	30	12
18	11	*Denhamia obscura*	16	9
20	15, 13	*Pouteria sericea*	12	9
14	8	*Miliusa brahei*	20	10
17	11, X	*Polyalthia nitidissima*	16	9
15	7, 16	*Strychnos lucida*	20	9
21	7	*Acacia auriculiformis*	40	16
4	2, 12	dead *Litsea*	7	7
8	4	mostly dead	20	11
19	17	termite ridden	8	7
X	X	dead slender tree (*Litsea* ?)	10	5

Trees used by Green Tree Frogs display a wide range of characteristics, from tall trees with dense foliage to low spreading species (Table 2), although the majority of trees are greater than seven metres in height (Table 1). There are also a range of bark types from smooth to fissured. As in other dry monsoon forests of the Northern Territory, a subset of the vegetation is deciduous during the dry season (Bach 2002). As a consequence, vegetative cover is less adequate and there is greater penetration of sunlight and potential for air movement during the dry season. These factors are likely to increase the importance of tree hollows as daytime refugia during this period.

Table 2. Characteristics of hollow-forming tree species used by *Litoria caerulea*.

Tree Species	Max. height (m)	Habit	Bark	Foliage	Leaf retention
Acacia auriculiformis	20	tall spreading	rough; fissured at base	dense	evergreen
Denhamia obscura	10	rounded crown	rough	pendulous	evergreen
Drypetes deplanchei	12	upright buttressed	smooth to slightly rough	dense	semi-deciduous
Ganophyllum falcatum	20	large tree	smooth to slightly coarse; flaking	dense	evergreen
Litsea glutinosa	15	slender upright	smooth to slightly rough	moderately dense	deciduous ?facultatively
Miliusa brahei	15	erect	rough, fissured	moderately dense	deciduous
Polyalthia nitidissima	20	upright	slightly rough	dense	evergreen
Pouteria sericea	10	erect	rough, finely fissured	moderately dense	evergreen
Strychnos lucida	6	low spreading	smooth to slightly rough	moderately sparse	facultatively deciduous

Hollows used by *L. caerulea* vary considerably in depth, from 8 to 30 cm, but the width of the opening is consistently less than 4 cm (Table 3). The majority of trees used are greater than 9 cm diameter at breast height (DBH: Table 1). Hollows are generally at head height or above, although they may be quite low, eg. Hollow 1 (Table 3). I have

only managed to record measurements for a subset of the hollows because several were inaccessible or the exact location could not be identified using radio-tracking techniques (Table 3), hence it is likely that the data are biased in favour of hollows nearer the ground (cf. Griffiths 1994).

Consideration of the microhabitat requirements of *L. caerulea* suggests that optimal hollows are likely to be those that retard moisture loss and secondarily may also reduce vulnerability to predators and competitors. A tight-fitting hollow is presumably optimal for maintaining moisture balance and in some situations the head of the animal may block the hollow; this may serve to reduce water loss and may also discourage predators. Potential predators at East Point include Children's Python *Liasis childreni*, Common Tree Snake *Dendrelaphis punctulata*, Slaty-grey Snake *Stegonotus cucullatus*, the monitor lizards *Varanus panoptes* and *V. scalaris*, and Pacific Baza *Aviceda subcristata*. Some hollows retain water during the wet season and the frogs have been observed to conceal themselves underwater when approached. Frogs also use man-made structures (ablution blocks) at East Point, which provide suitable shelter and moisture conditions.

Table 3. Characteristics of tree hollows used by *Litoria caerulea* at East Point Reserve. Tree species are listed in Table 1. Hollows 20u, 16, 21, and additional hollows (not listed) were inaccessible or could not be located precisely. l and u denote lower and upper respectively.

Hollow No.	Height above ground (m)	Width of opening (cm)	Hollow depth (cm)	Orientation	Hollow Type
11	6	4	10	diagonal	branch
15l	4	3	10	horizontal	trunk
15u	4.5	2.5	8	vertical	trunk
4	3	4	9	vertical	dead hollow trunk
1	0.6	1.5	4	vertical	slit/knot
17	1.6	2	10	vertical	in fork
2	2	1.5	30	vertical	fissure
23	1.5	2	8?	vertical	fissure
20l	4	2	8	vertical	trunk knot
20u	4+	?	?	?	knot ?
26	2.1	2	8	vertical	in fork
16	5+	?	?	?	branch ?
21	5+	?	?	?	?
X	1.1	5	20+	vertical	hollow trunk

On two occasions we have recorded two individuals using different hollows in the same tree, and at times we have observed two frogs using the same hollow. The choice of hollow may indicate individual preference for particular tree species; certainly it appears to be the case that distinct hollow types are selected by individual animals. A visual search of potentially suitable hollows was made in a portion of the forest, and a low level of occupancy was found, suggesting that frogs are selecting particular types of hollows as shelter sites. Surveys of tree frequency (unpubl. data) indicate that of the commonly utilised species *Litsea glutinosa* is relatively abundant in the forest patch at East Point, whereas, for example, *Ganophyllum falcatum* occurs at low densities. Also, although stem densities are exceedingly high (approximately 9000/ha), average DBH is low (Mean ± SD (cm): 5.55 ± 3.98) with few stems ≥ 9 cm DBH (~20%), and of these only some appear to have the potential to form hollows.

Green Tree Frogs appear also to use tree hollows in woodland habitats (often near water), but there is no data on the types of shelter sites in the range of other habitats that they occupy. In addition, I am yet to confirm whether (as I suspect) densities are highest in areas of moist microclimate such as rainforest patches. Finally, although Green Tree Frogs are widespread, common and frequently encountered, this study represents what is effectively the limit of the knowledge of the ecology of the species. Further research is required to describe the basic biology of this species, and indeed much of the Torresian herpetofauna.

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The Green Tree Frog *Litoria caerulea* is active both on the ground and in trees. (Paul Horner)